

CLAIMS

We claim:

1. A method of preparing a frame of a digital speech signal for compression comprising the steps of:

5 producing a linear prediction residual for the frame, the linear prediction residual having irregularly spaced dominant peaks;

dividing the residual into a series of contiguous, non-overlapping sections, each section containing not more than one dominant peak;

10 deriving an idealized signal having a series of regularly-spaced dominant peaks located in a series of sequential sections;

associating each section of the residual with a corresponding section of the idealized signal;

15 calculating a linear continuous warp contour for each residual section based on a subset of possible last sample lag values for each residual section within a subrange of possible last sample lag values for each residual section; and

20 modifying the residual by applying the calculated warp contour to the sections of the residual so that any dominant peak in each section of the residual aligns with the dominant peak in the corresponding section of the idealized signal, whereby dominant pitch peaks of the modified residual are regularly spaced, and no portion of any section of the residual is omitted or repeated in the modified residual.

2. The method according to claim 1 wherein the step of producing a linear prediction residual for the frame further comprises the steps of:

extracting linear prediction coefficients for the frame;

interpolating the linear prediction coefficients for the frame to create linear prediction coefficients for a plurality of sub-frames of the frame; and

producing a prediction residual for each sub-frame, whereby the prediction

5 residual for the frame comprises a set of sub-frame prediction residuals.

3. The method according to claim 1, wherein the step of dividing the residual into a series of contiguous, non-overlapping sections further comprises the steps of analyzing the frame to identify an integer pitch period.

10 4. The method according to claim 3 wherein the step of analyzing the frame to identify an integer pitch period further comprises the step of employing correlation analysis in the open loop.

15 5. The method according to claim 1, wherein the step of calculating a linear continuous warp contour for each residual section further comprises the steps of:

establishing a first sample lag for the first sample of the residual section;

identifying a set of candidates for the last sample lag for the last sample of the

20 residual section, the set of candidates consisting of a subset of all possible last sample lag values within a sub-range of all possible last sample lag values;

performing a linear interpolation between the first and last samples of the residual section for each candidate last sample lag to create a set of candidate lag contours;

5 applying each candidate lag contour to the residual section to obtain a set of candidate modified residuals;

calculating a correlation strength between each candidate modified residual and the corresponding section of the idealized signal to create a set of correlation strengths;

10 deriving an optimal last sample lag for the residual section based on the set of correlation strengths; and

deriving a linear continuous warp contour by interpolating linearly over the section from the first sample lag to the derived optimal last sample lag for the residual section.

15 6. The method according to claim 5, wherein the step of deriving an optimal last sample lag for the residual section based on the set of correlation strengths further comprises the steps of:

segregating the set of correlation strengths into overlapping subsections as a function of the last sample lags used to derive the strengths;

20 representing each subsection as a curve;

calculating the maximum value of each curve, wherein the maximum value is selectable from the group consisting of all possible lag values within a range of

possible lag values that includes the last sample lags used to derive the strengths in the subsection; and

calculating the maximum correlation strength for the section based on the maximum values for the curves of the subsections.

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7. The method according to claim 6 wherein the curve is a polynomial.

8. The method according to claim 7 wherein the polynomial is a quadratic function.

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9. The method according to claim 1, wherein the subrange of possible last sample lag values for each residual section is selected such that the greatest cumulative shift for any sample in the section upon application of the calculated warp contour will be less than four sample positions.

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10. An apparatus for modifying a speech signal prior to coding the speech signal, the apparatus comprising:

a linear prediction coefficient extraction module for receiving a digital speech signal and for producing a set of linear prediction coefficients;

20 an inverse synthesis filter for receiving the digital speech signal and the linear prediction coefficients and for producing a residual signal;

a residual modification module for time warping the residual signal based on a continuous linear warp contour selected from the set of all possible warp contours by

calculating only a subset of all possible warp contours, whereby a modified residual signal having a regular rather than irregular array of dominant peaks is produced; and

a synthesis filter for receiving the modified residual signal and the linear prediction coefficients for producing a modified digital speech signal suitable for low

5 bit rate coding.

11. The apparatus according to claim 10, further comprising a codebook excited linear prediction coder module for receiving the modified digital speech signal and for producing a compressed speech signal.

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12. A computer readable medium having computer readable instructions for performing a method of preparing a frame of a digital speech signal for compression comprising the steps of:

producing a linear prediction residual for the frame, the linear prediction

15 residual having irregularly spaced dominant peaks;

dividing the residual into a series of contiguous, non-overlapping sections, each section containing not more than one dominant peak;

deriving an idealized signal having a series of regularly-spaced dominant peaks located in a series of sequential sections;

20 associating each section of the residual with a corresponding section of the idealized signal;

calculating a linear continuous warp contour for each residual section based on a subset of possible last sample lag values for each residual section within a subrange of possible last sample lag values for each residual section; and

modifying the residual by applying the calculated warp contour to the sections of the residual so that any dominant peak in each section of the residual aligns with the dominant peak in the corresponding section of the idealized signal, whereby dominant pitch peaks of the modified residual are regularly spaced, and no portion of any section of the residual is omitted or repeated in the modified residual.

13. The computer readable medium according to claim 12 wherein the step of producing a linear prediction residual for the frame further comprises the steps of:

extracting linear prediction coefficients for the frame;

interpolating the linear prediction coefficients for the frame to create linear prediction coefficients for a plurality of sub-frames of the frame; and

producing a prediction residual for each sub-frame, whereby the prediction residual for the frame comprises a set of sub-frame prediction residuals.

14. The computer readable medium according to claim 12, wherein the step of dividing the residual into a series of contiguous, non-overlapping sections further

comprises the steps of analyzing the frame to identify an integer pitch period.

15. The computer readable medium according to claim 14 wherein the step of analyzing the frame to identify an integer pitch period further comprises the step of employing co-relation analysis in the open loop.

5 16. The computer readable medium according to claim 12, wherein the step of calculating a linear continuous warp contour for each residual section further comprises the steps of:

establishing a first sample lag for the first sample of the residual section;

10 identifying a set of candidates for the last sample lag for the last sample of the residual section, the set of candidates consisting of a subset of all possible last sample lag values within a sub-range of all possible last sample lag values;

performing a linear interpolation between the first and last samples of the residual section for each candidate last sample lag to create a set of candidate lag contours;

15 applying each candidate lag contour to the residual section to obtain a set of candidate modified residuals;

calculating a correlation strength between each candidate modified residual and the corresponding section of the idealized signal to create a set of correlation strengths;

20 deriving an optimal last sample lag for the residual section based on the set of correlation strengths; and

deriving a linear continuous warp contour by interpolating linearly over the section from the first sample lag to the derived optimal last sample lag for the residual section.

5 17. The computer readable medium according to claim 16, wherein the step of deriving an optimal last sample lag for the residual section based on the set of correlation strengths further comprises the steps of:

 segregating the set of correlation strengths into overlapping subsections as a function of the last sample lags used to derive the strengths;

10 representing each subsection as a curve;

 calculating the maximum value of each curve, wherein the maximum value is selectable from the group consisting of all possible lag values within a range of possible lag values that includes the last sample lags used to derive the strengths in the subsection; and

15 calculating the maximum correlation strength for the section based on the maximum values for the curves of the subsections.

 18. The computer readable medium according to claim 17 wherein the curve is a polynomial.

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 19. The computer readable medium according to claim 18 wherein the polynomial is a quadratic function.

20. The computer readable medium according to claim 12, wherein the subrange of possible last sample lag values for each residual section is selected such that the greatest cumulative shift for any sample in the section upon application of the calculated warp contour will be less than four sample positions.

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21. The computer readable medium according to claim 12, wherein the computer readable medium comprises a magnetically readable disc medium.

22. The computer readable medium according to claim 12, wherein the computer readable medium comprises an optically readable disc medium.

23. The computer readable medium according to claim 12, wherein the computer readable medium comprises a modulated data signal.

24. The computer readable medium according to claim 12, wherein the computer readable medium comprises volatile computer readable storage.

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